ATLAS Pixel Testbeam Results

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1 Introduction

The ATLAS Pixel Detector is the innermost subdetector of the ATLAS Inner Detector. The Pixel Detector provides a 3-point high precision tracking towards the vertex. This means a challenge of high spatial resolution for vertex finding especially for b-tagging, a high efficiency, fast read-out and a tolerance towards the design dose of $10^{15} n_{eq} cm^{-2}$.
The 3 layer structure of the Pixel Detector (see fig. 1) consists of 1744 Pixel modules (see fig. 2), each with 46080 pixels [1].

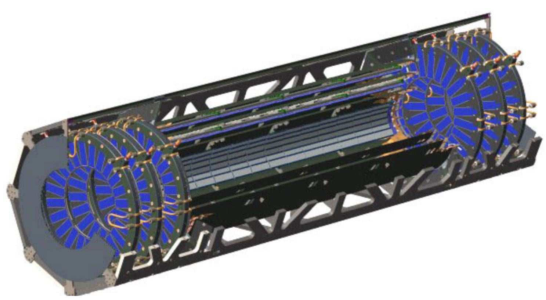

Fig. 1. ATLAS Pixel Detector with 2×3 disks and 3 barrel layers

Each Pixel Module is constructed in a hybrid style. It consists of a 250 μm thick sensor tile with outer dimensions of $21.4 \cdot 60.4$ mm^2. The sensor is connected to 16 front end (FE) chips via bump bonds. Together with the corresponding FE-cell, each 50 μm times 400 μm sized pixel provides data about position, timing and the deposited charge measured as time over threshold (ToT) of a passed particle [1]. All pixels get an individual threshold and calibration.

2 Testbeam Setup

Irradiated and not irradiated modules have been tested in the SPS with 180 GeV/c^2 pions.

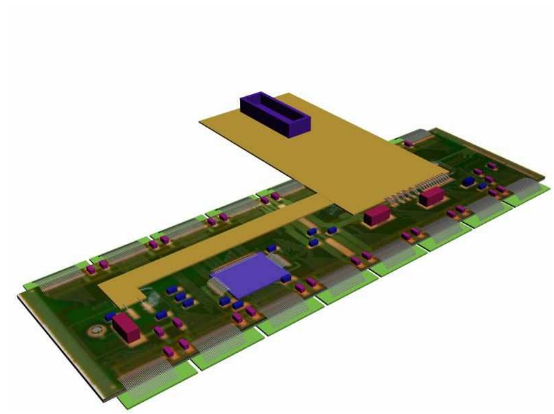

Fig. 2. Pixel module that consists of sensor, 16 FE chips, module control chip, flex circuit and the micro connector

For testbeam purposes a fast silicon strip telescope for tracking and a scintillator for triggering have been used (see fig. 3). These provide a location precision better than 6 μm .[4]

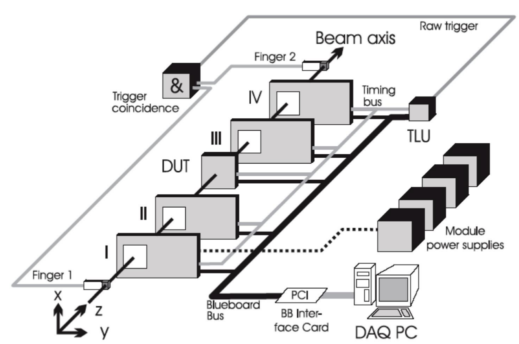

Fig. 3. Schematic view of Si-strip telescope with 4 x,y-telescope modules and a device under test (DUT) [4]

3 Analysis

The depletion depth i.e. the depth of active detector material is measured with impact angles of 30° for irradiated and not-irradiated modules with different biasvoltages. After the ATLAS Pixel lifetime dose of approx.

$1.1 \cdot 10^{15} n_{eq} cm^{-2}$ the sensor is nearly fully depleted with a bias voltage of 600 V. This is enabled by the use of oxygenated silicon as bulk material. With the use of standard silicon the needed depletion voltage after lifetime dose would be $\geq$ 2 kV [3]. The collected charge per m.i.p. is due to trapping in the silicon reduced by approx. 20% after irradiation [2], but still well above the pixel's threshold.

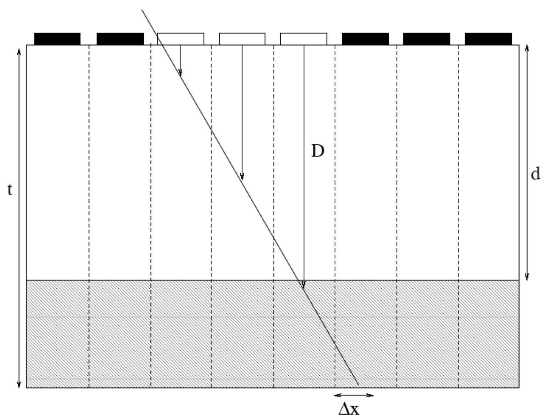

Fig. 4. Schematic cross section of sensor bulk with particle passing several pixel volumes to illustrate depth measurement [2]

The charge collection in the pixel is quite uniform, as figure 5 illustrates, exept along the edges and near the bias dot due to bending of the electric field of the bias voltage in these areas. The bias dot is a structure on the pixel's surface for quality assurace purposes. The charge loss increases with irradiation in the dot's area from 10% to 30%.

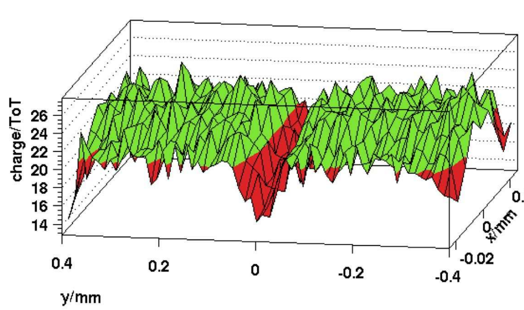

Fig. 5. Average charge distribution (in units of ToT) for tow adjacent pixels of different columnpairs

With the irradiation of modules their signal gets more noisy than before so that a higher threshold is needed for operation. Due to this and the mentioned reduction of signal height the particle detection efficiency decreases from its originally $\geq$99%.

Further increasing of the threshold leads to futher loss of detected tracks, especially along the pixel's edges and in the bias dot region like shown in figure 6.

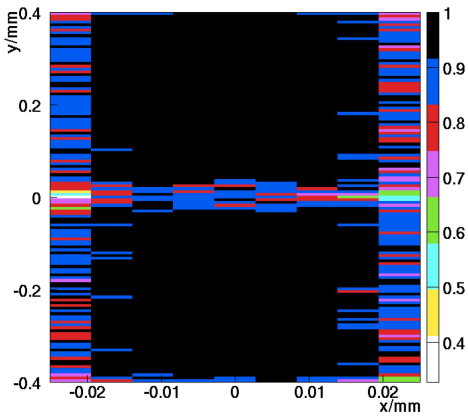

Fig. 6. Growing inefficiency for tow adjacent pixels of different columnpairs

4 Outlook

At the moment studies are going on concerning the sensor's threshold behavior, more studies of the bias dot's chargeloss for different dose levels. General performances of production modules tested in the beam will be presented.

References

[1] The ATLAS Pixel collaboration, ATLAS Pixel Detector Technical Design Report, CERN/LHCC/98-13 (CERN 1998)

[2] T. Lari et al., Test Beam Results of ATLAS Pixel Sensor, arXiv:hep-ex/0210045 v1 (2002)

[3] F. Hügging, Der ATLAS Pixelsensor - Der state-of-the-art Pixelsensor für teilchenphysikalische Anwendungen mit extrem hohen Strahlungsfeldern, Ph.D. thesis, Universität Dortmund, (Dortmund 2001)

[4] J. Treis et al., A modular PC based silicon microstrip beam telescope with high speed data acquisition, arXiv:physics/0210004 v1 (2002)